The Integrated Medical Model

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☐To develop an integrated, quantified, evidence-based decision support tool useful to crew health and mission planners.

☐To help align science, technology, and operational activities intended to optimize crew health, safety, and mission success.

Scope and Approach

IMM addresses in-flight risk only, and uses ISS data as stepping stone

☐ Scope

- ☐ Forecast medical outcomes for <u>in-flight operations only</u>
- ☐ Forecast <u>medical impacts to mission</u>
- ☐ <u>Does not assess</u> long-term or chronic <u>post-mission medical consequences</u>

☐ Approach

- ☐ Use ISS data as stepping stone to Exploration Program
- ☐ Employ best-evidence clinical research methods
- ☐ Employ Probability Risk Assessment (PRA) techniques
- ☐ Collaborate with other NASA Centers and Organizations

What is IMM?

- A software-based decision support tool
  - Forecasts the impact of medical events on space flight missions
  - Optimizes the medical system within the constraints of the space flight environment during simulations.

Software Technologies

Several software technologies are used to operate and manage risk assessments, reports, and refinements to IMM

- IMM - SAS (Statistical Analysis Software)
- Optimization – SAS
- Database – SQL
- Citation Management – RefMan
- Report Generation – Aspose
- Workflow and Configuration Management - SharePoint

Capability Status

- IMM 2.1/3.0
  - Locked down and undergoing clinical validation
  - Available for risk assessments, trade studies
- 83 medical conditions represented (47 of 83 medical conditions have been recorded to occur in flight)
- In-flight medical resources identified per medical condition
- ³0HGLFDO´³RSHUDWLRQDO´RU³H U classification of risk drivers
- Established database; build out continues
- Integrated citation management software

Who can benefit from IMM capabilities?

- **Flight Surgeons**
  - What in-flight medical threats are greatest for reference mission A?

- **Risk Managers**
  - What is the risk of evacuation - due to a medical event - for a 6-person, 180 day mission assuming the current in-flight medical capability?

- **Vehicle Designers**
  - :KDW¶V WKH RSWLPXP PHGLFDO PDVV DOORFDWLRQ IRU JLY

- **Health Care System Designers**
  - What medical items do we fly for a given mass/volume allocation?

- **Trainers**
  - How do I prioritize limited crew training hours?

- **Requirement Managers**
  - :KDW¶V WKH UDWLRQDOH IRU WKLV FUHZ KHDOWK UHTXLUH

- ISS medical system redesign rationale
- Storage Capacity Requirements of Vomitus/Diarrhea for Constellation
- ExMC List of Prioritized Medical Conditions
- ExMC Technology Watch
- Orion medical kit design support
- ISS Probabilistic Risk Assessment Updates
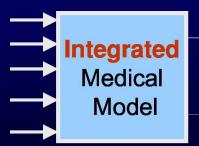
Comparison – 5x5 Risk Matrix vs. IMM

Likelihood

Outcome

5x5 Matrix

- ☐ Qualitative
- ☐ Categorical
- ☐ Subjective
- ☐ Single Risk
- ☐ No Uncertainty
- ☐ No Confidence Interval
- ☐ Limited context

IMM

- ☐ Quantitative
- ☐ Probabilistic, Stochastic
- ☐ Evidence-based
- ☐ Integrated Risks
- ☐ Uncertainty
- ☐ Confidence Interval
- ☐ In context

- Medical Conditions & Incidence Data
- Crew Profile
- Mission Profile & Constraints
- Crew Functional Impairments
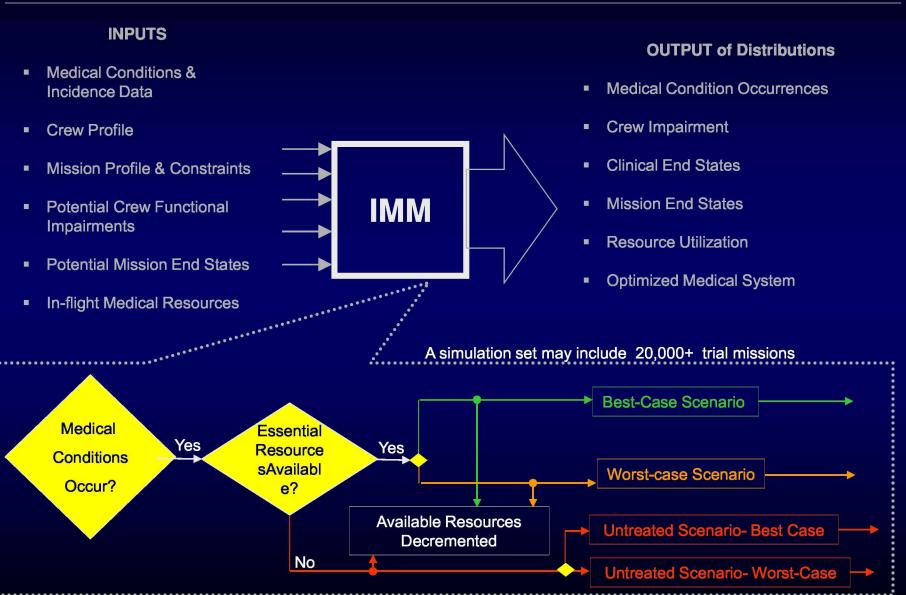- In-flight Medical Resources

Integrated Medical Model

- Medical Condition Occurrences
- Crew Impairment & Clinical End States
- Resource Utilization
- Optimization of Vehicle Constraints and Medical System Capabilities
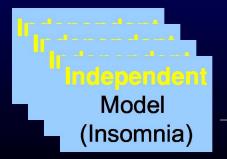
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IMM Logic

INPUTS

- Medical Conditions & Incidence Data

- Crew Profile

- Mission Profile & Constraints

- Potential Crew Functional Impairments

- Potential Mission End States

- In-flight Medical Resources

IMM

OUTPUT of Distributions

- Medical Condition Occurrences

- Crew Impairment

- Clinical End States

- Mission End States

- Resource Utilization

- Optimized Medical System

A simulation set may include 20,000+ trial missions

Medical Conditions Occur? — Yes → Essential Resources Available? — Yes → Best-Case Scenario

Worst-case Scenario

Available Resources Decremented

No

Untreated Scenario- Best Case

Untreated Scenario- Worst-Case

Independent Risk Models & IMM

Risk Drivers
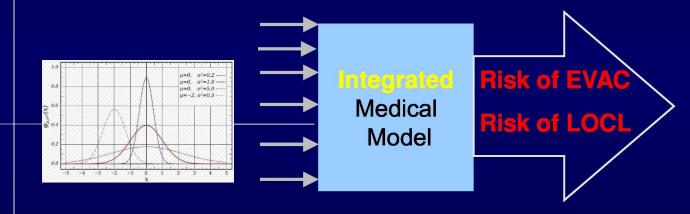
Independent Model (Renal Stone)

Independent Model (Bone Fracture)

Independent Model (Insomnia)

Integrated Medical Model

Risk of EVAC

Risk of LOCL

For a specified mission scenario, the output from independent models can provide distributions of incidence data.

Innovations & Lessons Learned

- Clinical Findings Form¹
- Essential vs. Nonessential medical items
- Untreated Best-Case/Worst-Case Scenario
- Level of Evidence Scale for Space Medicine
- Optimization Algorithms
- Space Adaptation Syndrome Incidence Proportions

IMM Evidence Base

- Longitudinal Study of Astronaut Health
- ISS Expeditions 1 thru 13 (2006)
- STS-01 thru STS-114 (2005)
- Analog, terrestrial data
- Review of crew medical charts
- Flight Surgeon Delphi Study

- Russian medical data **not** used

- **Goal**
  - Identify a medical kit that maximizes Crew Health Index while meeting mass and volume constraints
  - Mass < 3.31 kg
  - Volume < 4054.22 cm^3
  - Assume 30% packing factor

- **Mission Scenario**
  - Crew of four
  - 3-day Orion transfer mission

- **Success Criterion**
  - The optimized medical kit approaches a risk profile of a medical kit with unlimited resources

Orion Medical Kit Design - Results

Attribute	"Bottomless" Kit	Optimized Kit
Mass (kg)	43.60	3.25
Volume (cm^3)	144684	4940
CHI (95% C.I.)	84.55 (67-93)	84.34 (66-93)
Risk of EVAC	0.07%	1.07%
Risk of LOCL	0.01%	0.02%

Crew Health Index (CHI)

"Bottomless" Kit

Optimized Kit

- A shoebox size kit can be designed to treat the conditions that have a high probability of occurring during a 3-day mission without a reduction in CHI from the fully treated scenario.

- The trade-off is that the kit does not include resources to treat low probability, worst-case scenario conditions, leading to an increase in the probability of evacuation from the fully treated scenario.

Validation – ISS Risk of EVAC Rates

IMM forecasted EVAC rates compare favorably with literature review EVAC rates (0.010 to 0.072)

Source	Low (events/person-yr)	Max (events/person-yr)
IMM	0.021	0.030*
Terrestrial General Population	0.060	-
Antarctic Population	0.036	-
U.S. Submarine Population	0.023	0.028
Russian Historical Space Flight Data	0.032	0.072
LSAH Data	0.010	0.020
Space Station Freedom Clinical Experts Seminar Proceedings (1990)	0.010	0.030

* Reference Mission 2: 6 crew, 6 month mission

Validation – ISS Risk of LOCL

**IMM forecasted LOCL rates compare favorably with
literature review results for LOCL rates (0.0029 to 0.0081)**

Source	LOCL (events/person-yr)
IMM (3 crew/6-month mission)	0.0053
IMM (6 crew/6-month mission)	0.0046
Terrestrial Mortality Rate	0.0081 (2006)
48-year old male	0.0048 (2005)
48-year old female	0.0029 (2005)
Antarctic	0.0054 (1904-1964)
LSAH Data	0.0054 (1959-1991)

Validation - Sensitivity Analysis

IMM Simulation Data

Medical (58%)

1. Kidney Stone
2. Exposed Dental Pulp
3. Skin Infection
4. UTI (female)
5. Sepsis
6. Atrial fibrillation

Injury/Trauma (25%)

1. Chest Injury
2. Wrist Fracture
3. Eye Abrasion

Environmental (17%)

1. Toxic Exposure
2. Smoke Inhalation

Actual Russian Flight Data

Three EVACs

1. Urosepsis
2. Cardiac Arrhythmia
3. Toxic Exposure

Three Close Call EVACs

1. Kidney Stone
2. Dental Abscess
3. Toxic Exposure

NOTE: No Russian input data is in IMM

Next Steps through Sept 2010

□ Validation of IMM 3.0 per plan (Jan-July)

□ IMM Database 3.0 Development (Jan-July)

□ Complete Ops Documentation (July)

□ Operational Acceptance Review (Aug)

□ Delivery of IMM 3.0 (Sept)

□ Delivery of Database 3.0 (Sept)

□ IMM 4.0 Development (Feb-Sept)

□ Transition to Operations (1 October 2010)

IMM addresses the observations documented by the RTF Task Group

«H[SHULHQFHDQGLQVWLQFWDUHSRRUVXE careful analysis of uncertainty«

«7KLVUHTXLUHVWKDWDQDO\WLFDOPRGHO appropriately to inform decisions«

* Source: *NASA Return to Flight Task Group Final Report: Annex A.2 Individual Member Observations* by Dr. Dan L. Crippen, Dr. Charles C. Daniel, Dr. Amy K. Donahue, Col. Susan J. Helms, Ms. Susan Morrisey Livingstone, Dr. Rosemary O'Leary, and Mr. William Wegner.

Questions?